RADIO WAVES

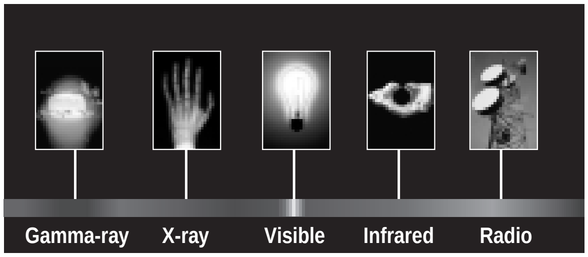
BACKGROUND:

The **electromagnetic spectrum** consists of waves of many **wavelengths** ranging from very long wavelength radio waves to very short wavelength **gamma rays**. Visible light, consisting of short wavelength waves, is placed near the middle of this spectrum.

Visible light can pass through window glass, but a solid wall will absorb a portion of the light and reflect the remaining portions. Scientists would say that glass is transparent to visible light, but a wall is opaque.

Since the atmosphere is transparent to visible light (while absorbing some of the light), astronomers who use telescopes can see things from far away using visible light to form images.

Earth's atmosphere, however, acts as an opaque barrier for much of the electromagnetic spectrum. The atmosphere absorbs most of the wavelengths shorter than



ultraviolet, most of the wavelengths between infrared and microwaves, and most of the longest radio waves. For radio astronomers this leaves only short wave radio to penetrate the atmosphere and bring information about the universe to our Earth-bound instruments. The main frequency ranges allowed to pass through the atmosphere are referred to as the radio window. The radio window consists of frequencies that range from about 5 MHz (5 million hertz) to 30 GHz (30 billion hertz). The low-frequency end of the window is limited by signals being reflected by the ionosphere back into space, while the upper limit is caused by absorption of the radio waves by water vapor and carbon dioxide in the atmosphere. As atmospheric conditions change the radio window can expand or shrink. On clear days with perfect conditions signals as high as 300 GHz have been detected.

It is the effects of the ionosphere on the lower end of the radio spectrum that we will investigate in this exercise.

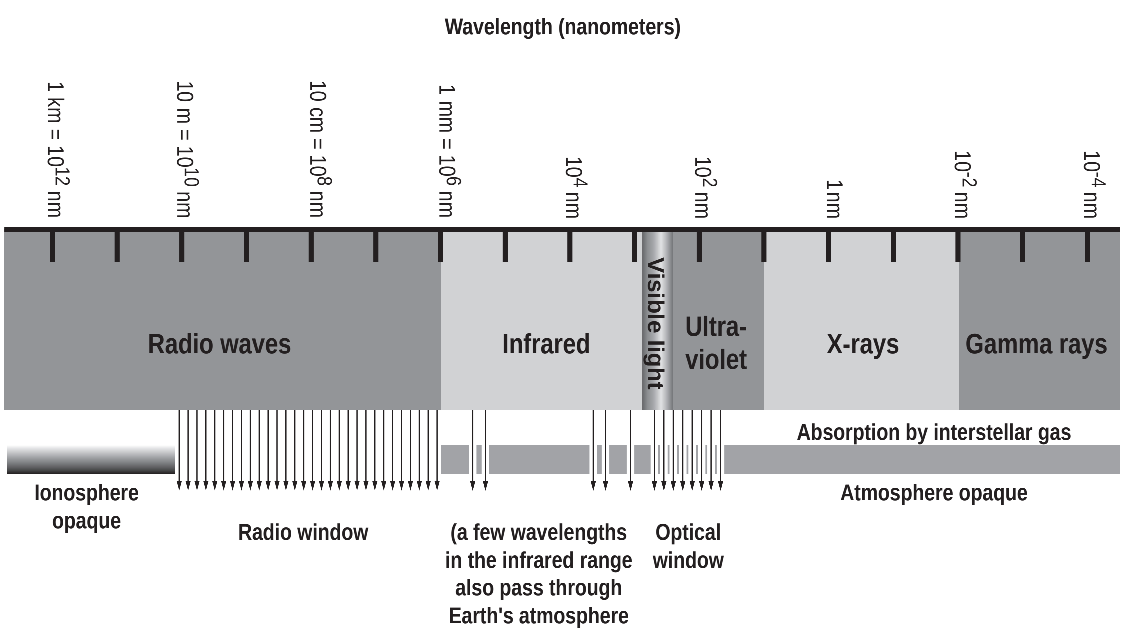
THE IONOSPHERE

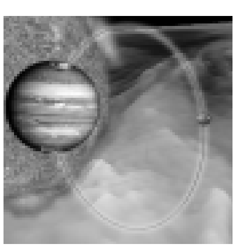
The ionized part of the Earth's atmosphere is known as the ionosphere. **Ultraviolet light** from the Sun collides with atoms in this region knocking electrons loose. This creates ions, or atoms with missing electrons. This is what gives the Ionosphere its name and it is the free electrons that cause the reflection and absorption of radio waves.

How does this affect our observations?

When the Sun is overhead during the day, most of the ionosphere is ionized due to the large amount of ultraviolet light coming from the Sun. As radio waves enter Earth's atmosphere from space some of the waves are absorbed by the electrons in the ionosphere while others pass through and are detectable to

Atmospheric Windows to Electromagnetic Radiation





ground-based observers. The frequency of each of these waves is what determines whether or not it is absorbed or able to pass through the atmosphere. Low-frequency radio waves do not travel very far through the atmosphere and are absorbed rather quickly. Higher frequency waves are able to pass through the atmosphere entirely and reach the ground.

This process also works in reverse for radio waves produced on the Earth. The high-frequency waves pass through the ionosphere and escape into space while the low-frequency waves reflect off the ionosphere and essentially "skip" around the Earth.

The diagram below will help illustrate this.

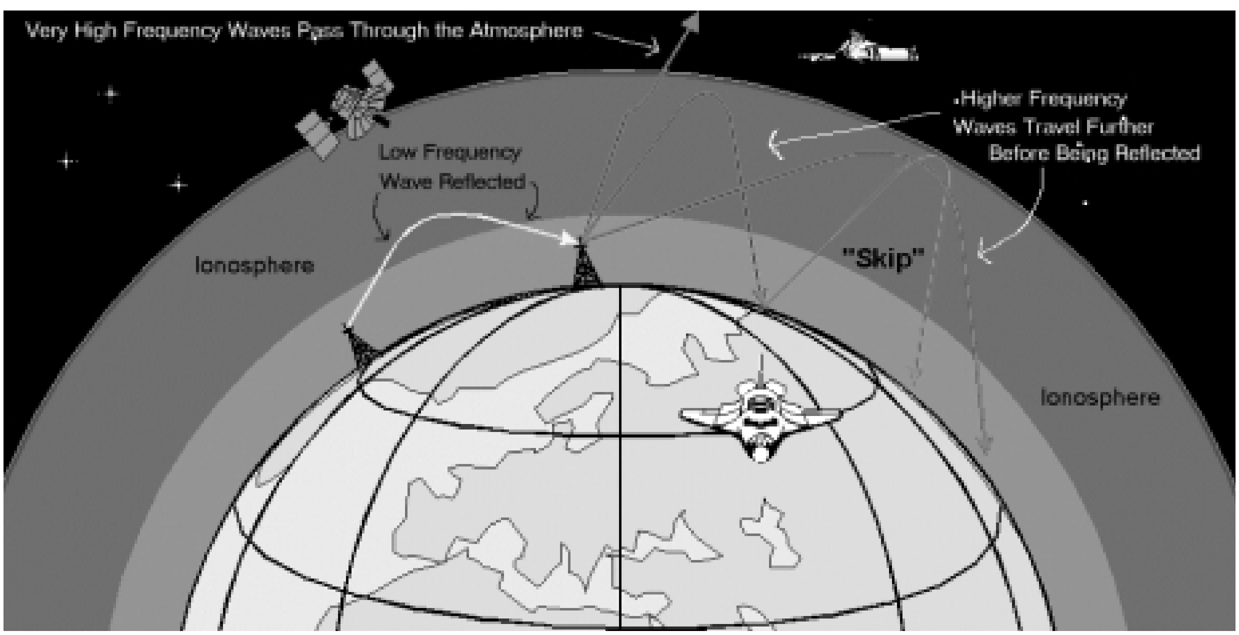
What's all this talk about high-frequency and low-frequency radio waves? What types of things fall in each range?

Astronomical radio sources emit over a wide range of frequencies. Their emission can be measured ranging from low frequencies to high frequencies. Jupiter for example emits radio waves from about 10 kHz up to about 300 GHz, while the Sun emits radio waves in all wavelengths. This emission is broken into several groupings. The lowest being the kilometric emission that ranges from 10 kHz up to 1000 kHz. Other frequency groups include hectometric (1000 KHz to 3 MHz), decametric (3 MHz to 40 MHz), and decimetric (100 MHz to 300 GHz). It is the decametric emissions that we are concerned about with Radio Jove. The Radio Jove receiver is tuned to a frequency of 20.1 MHz.

Radio waves produced on Earth are mostly man-made and are often at one specific frequency. In fact, this is one way astronomers can tell a signal created on Earth apart from an astronomical signal. If they are able to tune their receivers to a slightly higher or lower frequency and the signal disappears it is most likely an Earth-based signal. Radio waves fall into three main categories with a variety of uses:

H.F. (High Frequency 3 to 30 MHz)

- Long range communications. Shipping, aircraft, world broadcast communications, radio amateurs.
- Use involves reflecting the signal off the ionosphere back down to waiting receiving stations. Prone to atmospheric changes causing fading and noise.
- Range from 500 to thousands of kilometers.



V.H.F. (Very High Frequency 30 to 300 MHz)

- Medium-range communications. Fleet vehicles, mobile, coastal shipping and air-to-tower communications.
- Range 70-100 km (aircraft several hundred km).

U.H.F (Ultra High Frequency 300 to 3000 MHz)

- This is the domain of such things as police hand-held radios, cell phones, T.V., and spacecraft-to-ground communications. In the high U.H.F. range the signal can "bounce" off buildings and reflect until it is detected by a receiver.

See additional activity:

http://radiojove.gsfc.nasa.gov/class/educ/radio/tran-rec/exerc/iono.htm

NATIONAL STANDARDS:

National Science Education Standards (NSES)

Grades 5-12

Middle school students grades 6-8 can learn about the electromagnetic spectrum, including the assertion that it consists of wavelike radiations. Wavelength should be the property receiving the most attention but minimal calculations.

High school students are ready to add the power of mathematics. Students at a sufficient minimum should develop semi-quantitative notions about waves—higher frequencies have shorter wavelengths and those with longer wavelengths tend to spread out more around objects. (Project 2061)

Mathematics (NCTM) Standards

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
- Use mathematical models to represent and understand quantitative relationships.
- Apply appropriate techniques, tools and formulas to determine measurements.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Develop and evaluate inferences and predictions that are based on data.

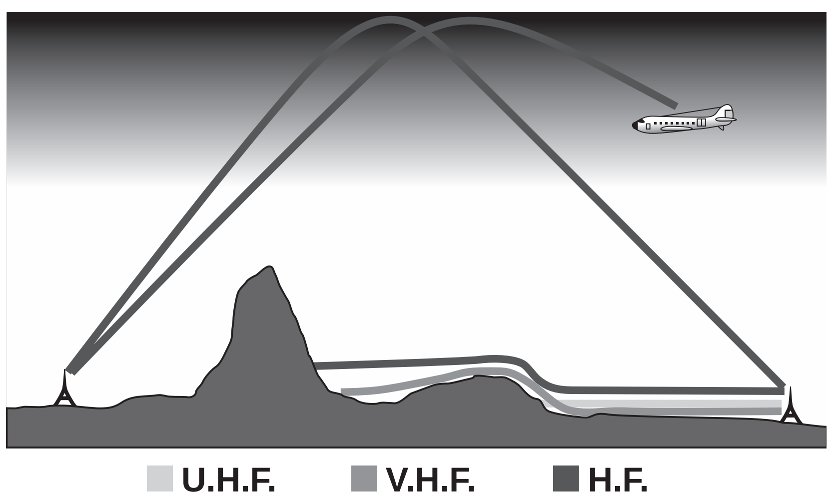
Science (NSE) Standards

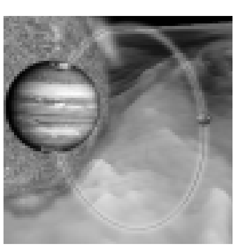
- Abilities necessary to do scientific inquiry.
- Understandings about scientific inquiry.
- Earth in the solar system.
- Understandings about science and technology.

Benchmarks for Science Literacy (Project 2061)

Grades 6-8

- Vibrations in materials set up wavelike disturbances that spread away from the source. Sound and earthquake waves are examples. These and other waves move at different speeds in different materials.





Grades 9-12

- Accelerating electric charges produce electromagnetic waves around them. Varieties of radiation are electromagnetic waves: radio waves, microwaves, radiant heat, visible light, ultraviolet radiation, x-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma waves, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light."

Technology for All Americans (ITEA) Standards

- Develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology (NET) Standards

- Select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems.

INSTRUCTIONAL OBJECTIVES:

- Students will identify radio waves on the electromagnetic spectrum.
- Students will utilize radio waves as a method of predicting the visual connection of the Sun and Earth, an aurora.

VOCABULARY:

- **Electromagnetic spectrum** consists of waves of many wavelengths ranging from very long wavelength radio waves to very short wavelength gamma rays. Visible light, consisting of short wavelength waves, is placed near the middle of this spectrum.
- **Radio waves** are energy waves produced by charged particles naturally emitted by the Sun, other stars and planets.
- **Visible light** can pass through window glass, but a solid wall will absorb a portion of the light and reflect the remaining portions. Scientists would say that glass is transparent to visible light, but a wall is opaque. Visible light is the region of the electromagnetic spectrum that can be perceived by human vision.
- **Ionosphere** is the ionized part of the Earth's atmosphere. Ultraviolet light from the Sun collides with atoms in this region knocking electrons loose.

ACTIVITIES:

ACTIVITY 1-A Scientific Notation and the Speed of Light

Radio waves, like all electromagnetic waves, travel at the speed of light–300,000,000 meters per second (3 hundred million meters per second). The speed of light is obviously a large number. In working with this number, and other large numbers, it is convenient to express it in scientific notation. In **scientific notation**, powers of ten are used to represent the zeros in large numbers. The following table shows how this is done.

Number	Name	Power of ten
1	one	10^0
10	ten	10^1
100	hundred	10^2
1000	thousand	10^3
10000	ten thousand	10^4
100000	hundred thousand	10^5
1000000	million	10^6
10000000	ten million	10^7
100000000	hundred million	10^8
1000000000	billion	10^9

If you examine the first and last columns, you can see that the power of ten is the same as the number of zeroes in the number. So the speed of light, which is 3 followed by 8 zeroes, becomes 3×10^8 meters per second. The standard symbol for the speed of light is **c**, so we can write:

$$c = 3 \times 10^8 \text{ m/s}$$